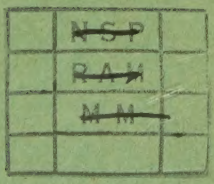
ANNUAL REPORT

of the

WEST AFRICAN RICE RESEARCH STATION



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WEST AFRICAN RICE RESEARCH STATION

Visit of H.R.H. Prince Philip, Duke of Edinburgh

ANNUAL REPORT

of the

WEST AFRICAN RICE RESEARCH STATION

1961

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Published by the
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THE SIERRA LEONE GOVERNMENT

ADMINISTRATIVE AND PROFESSIONAL STAFF

at 31st March, 1962

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INTRODUCTION

Last year's report was introduced by a brief discussion on the relationship of the rice plant to its environment. It was pointed out that the full potential yield of a rice plant can only be obtained under the optimum environmental conditions. In the case of light and temperature, practical control in the field is difficult and the production of varieties widely adaptable to these factors is necessary. The supply of nutrients to the plant is however much more easily modified in the field and the question of adaptability of the plant to a wide range of fertility is thus of less importance. Increased yield in this respect is therefore more easily obtained by modifying the environment rather than the genetic constitution of the rice plant. This does not mean however that all rices will give equally increased yields under higher supply of nutrients. Responses to fertilizer supply differ between varieties and improvement work at the present time pays attention therefore to the question of nutrient response, with the aim of producing varieties capable of taking full advantage of the higher nutrient levels now possible.

The optimum supply of nutrients to the rice plant in the field is not however a simple matter. Widespread fertilizer trials can be carried out, and the results of these can indicate fertilizer applications that will give immediate increase in yields in specific areas. Such trials are however costly, and the information obtained is limited. The results apply only to the immediate area of the trial and cannot confidently be applied elsewhere. And although increases in yield may be obtained, there is no indication whether these are the full increases that could be possible. While straightforward fertilizer trials are therefore of use in the short term immediate increase of yields, more fundamental studies of the subject are necessary in order to realize the full yield potential of the rice plant and in order to do this in the most economical manner.

In the first place it is necessary to know the nutrient requirements of the rice plant in its different stages of growth, in order to determine what fertilizers to apply and the best time to apply them. Investigations in Japan on the yield components of rice and the effects of fertilizers on them have done much in recent years towards elucidating this second point. As a result yield responses to fertilizers are now being obtained in many places by careful timing of the application, where in the past no increased yields have been obtained from similar amounts of fertilizers applied at a different stage of growth.

It is also necessary to have a clear understanding of the chemistry of rice soils, not only individual specific analyses to determine which nutrients are present and which are lacking, but more fundamental studies of the basic principles underlying the behaviour of nutrients in the soils. The presence of a specific nutrient, or even the addition of such nutrient, does not necessarily mean that it will be available to the rice plant, and unless its behaviour in the soil is understood, much time and money could be wasted. Whereas knowledge of the chemistry of soils in general is considerable, that of rice soils, which are usually submerged and waterlogged for considerable parts of the year, is not great. And the chemistry of soils in these conditions is likely to differ to a large extent from that of normal aerated soils. Now that work on the problems of acidity is mangrove soils is easing, the work of the Soils Section at Rokupr is therefore concentrating more on the general problems of the chemistry and fertility of submerged soils.

In such soils the state of reduction of the soil is important and affects the availability of nutrient to the rice plant and the release in the soil of toxic substances. Studies are being carried out therefore of the state of reduction of soils in conjunction with the growth of rice on them, and attempts are being made to define healthy reducing conditions and even more specifically the optimum reducing conditions for rice growth. Iron plays an important part in this, and a measure of the reducing condition of the soil can be determined by the ratio of ferrous to ferric iron present.

The results of this work should not only be of value in West Africa, in raising yields of rice and enabling more extensive areas to be developed for this crop, but should add considerably to the world's basic knowledge, strengthening the foundation on which increased yields can be built up in other rice growing countries.

ADMINISTRATION

Details in this section of the report cover the financial year, April 1961 to March 1962.

STAFF

Administrative and Professional

Mr. H. D. Jordan, Director, went on leave at the beginning of June and returned at the end of November, after paying a visit to the Far East.

Dr. P. R. Hesse, Soil Chemist, returned from leave at the end of August, and then went on to Nigeria, where he has been posted for the tour at Benin.

Dr. E. H. Roberts, Plant Physiologist, went on leave at the beginning of May and returned at the beginning of September, and Mr. R. Q. Craufurd, Plant Breeder, was on leave from late April to late August. Mr. A. J. Carpenter, Plant Breeder, took short leave from early January to mid-February.

Dr. M. G. R. Hart, Soil Microbiologist, went on leave at the beginning of September. Mr. J. W. O. Jeffery, Soil Chemist, was in post throughout the year.

At the beginning of April, Mr. R. A. Bohun of the Sierra Leone Department of Agriculture was replaced as Station Manager by Mr. W. E. A. French. Mr. P. J. Rooksby was appointed specifically to this post at the beginning of November, when Mr. French returned to the Department of Agriculture.

Mrs. Enid Jeffery has continued to assist in the library and at the beginning of December she was appointed as temporary Soil Chemist.

Mr. E. E. Harris, Executive Officer, was on leave from late December until mid-April.

Clerical and Technical

The position with regard to clerical staff has remained the same, four of the six posts being filled with temporary clerical assistants.

The laboratory staff position has also been unsatisfactory only four out of six Laboratory Assistants and three out of four Laboratory Attendants being available at the end of the year.

Field staff of the Department of Agriculture continue to work at the station and the position with these has remained satisfactory.

Unestablished Staff and Labour

Junior staff grades have continued to be easy to fill and are at full strength. The labour force averaged 106 throughout the year.

PUBLICATIONS

The 1959 Annual Report was received and distributed and the 1960 Report was received from the printer at the end of the year. Brief Quarterly Progress Reports continue to be issued.

The following papers have been published during the year:—

"The West African Rice Research Station", H. D. Jordan, Nature, **190,** 773-774. (1961).

"Estimation of Percentage Natural Cross-Pollination: Experiments on Rice", E. H. Roberts, R. Q. Craufurd and F. LeCochec, Nature, **190.** 1084-1085. (1961).

"Viability of Cereal Seed for Brief and Extended Periods", E. H. Roberts, Annals of Botany N.S., **25.** 373-380. (1961).

"The Viability of Rice Seed in relation to Temperature, Moisture Content and Gaseous Environment", E. H. Roberts, Annals of Botany N.S., **25.** 381-390. (1961).

"Dormancy in Rice Seed. I. The Distribution of Dormancy Periods", E. H. Roberts, Journal of Experimental Botany, **12.** 319-329. (1961).

"Dormancy in Rice Seed. II. The Influence of Covering Structures", E. H. Roberts, Journal of Experimental Botany, **12.** 430-445. (1961).

"Dormancy in Rice Seed. III. The Influence of Temperature, Moisture and Gaseous Environment", E. H. Roberts, Journal of Experimental Botany, **13.** 75-94. (1962).

"Measuring the State of Reduction of a Waterlogged Soil", J. W. O. Jeffery, Journal of Soil Science, **12.** 317-325. (1961).

"Phosphorus Fixation in Mangrove Swamp Muds", P. R. Hesse, Nature, **193.** 295-296. (1961).

"The Decomposition of Organic Matter in a Mangrove Swamp Soil", P. R. Hesse, Plant and Soil, **14.** 249-263. (1961).

"Some Differences between the Soils of Rhizophora and Avicennia Mangrove Swamps in Sierra Leone", P. R. Hesse, Plant and Soil, **14.** 335-346. (1961).

"A Turbidimetric Method for Determining Elemental Sulphur", M. G. R. Hart, The Analyst, **86.** 472-475. (1961).

"Storage of Cereal Seed in the Humid Tropics with special reference to Rice", E. H. Roberts, CCTA/FAO Symposium on Stored Food. (1962).

"Methods of improving Rice Quality by Post-Harvesting, Drying and Parboiling Techniques", R. Q. Craufurd, CCTA/FAO Symposium on Stored Food. (1962).

The following papers have been submitted for publication and are in the press:—

"Some Useful Techniques in Speeding up Rice Breeding Programmes", A. J. Carpenter and E. H. Roberts, Journal of Experimental Agriculture, 1962.

"Moisture Changes in Raw Paddy and Parboiled Paddy in West Africa and their influence upon Milling Quality. I. Moisture Changes in the Ripening Crop", R. Q. Craufurd, Empire Journal of Experimental Agriculture, 1962.

"Moisture Changes in Raw Paddy and Parboiled Paddy in West Africa and their influence upon Milling Quality. II. Changes during Drying", R. Q. Craufurd, Empire Journal of Experimental Agriculture, 1962.

"Observations on the Source of Acid in Empoldered Mangrove Soils. I. Formation of Elemental Sulphur", M. G. R. Hart, Plant and Soil, (1962).

"Observations on the Source of Acid in Empoldered Mangrove Soils. II. Oxidation of Soil Polysulphides", M. G. R. Hart, Plant and Soil. (1962).

TOURING AND VISITS

Mr. Jordan toured rice-growing countries in the Far East between the beginning of September and mid-November. He spent three weeks in Japan and paid briefer visits to Hong Kong, the Philippines, Thailand, Malaya, Burma, Ceylon, and Orissa and Madras in India. During this time he was able to visit some of the main rice producing areas in these countries and get a general picture of local methods of rice cultivation, and to have discussions with research workers and see the research work on rice that is in progress. In January Mr. Jordan paid a brief visit to Nigeria.

Mr. Carpenter spent two weeks visiting rice growing areas in Ghana in late September, and Mr. Craufurd similarly visited Gambia and Senegal in mid-October.

Messrs. Jordan, Roberts and Craufurd attended the joint CCTA/FAO Symposium on Stored Food held in Freetown in February.

In Nigeria, Dr. Hesse paid visits to the Federal Rice Research Station at Badeggi and the Niger delta area, and in Sierra Leone regular visits by staff were made to station extension areas at Mando, Kontobe, Torma Bum and Wellington.

VISITORS

The station presented a display stand at the Royal Agricultural Show at Kenema in November, which was visited by Her Majesty the Queen and His Royal Highness Prince Philip, Duke of Edinburgh and many other distinguished visitors. His Royal Highness honoured the station by a visit on 30th November, when he inspected the farm and laboratories and took lunch with the staff.

His Excellency Sir Maurice Dorman, G.C.M.G., Governor-General of Sierra Leone, accompanied by Lady Jackson, the economist from Britain, paid a brief visit to the station in December.

The Swiss Ambassador in Ghana, Mr. R. J. Keller, called at the station at the end of April, and the American Ambassador, Mr. A. S. J. Carnahan, accompanied by Messrs. C. M. George and F. Lamar King from his embassy, visited the station for one night in early March. Mr. H. K. Richwine of the American Embassy paid a brief visit in July and Messrs. J. D. Bartlett and R. H. Wengel in February.

The British High Commissioner, Mr. J. B. Johnston, and the Honourable Mahmoud Ahmed, Resident Minister Northern Province, called in January when they accompanied a delegation from the British Parliament consisting of the Rt. Hon. Sir John Vaughan-Morgan, the Rt. Hon. James Griffiths, and Messrs. D. Gibson-Watt and D. W. Wade. Mr. H. R. M. Farmer, Clerk to the British House of Commons was also in the party.

Other overseas visitors included Professor W. B. Fisher from Durham University in May, and Dr. and Mrs. J. M. Holmes in February, both

from Britain, and Professor Abou Zeid of the International Labour Office in March.

The Station Committee met at Rokupr in December. Mr. J. F. G. Sykes, Administrator of the West African Research Office, was in the chair; Nigeria was represented by Mr. J. E. Y. Hardcastle and Mr. J. C. Obi ; Ghana by Mr. A. L. Adu; and Sierra Leone by Mr. J. M. Dent.

Other visitors from West Africa included Dr. F. W. Hauck, FAO Regional Soil Fertility Specialist, in June; Mr. J. F. M. Sluyters of the Nigerian Federal Rice Research Station in July; Mr. C. W. S. Hartley, Director of the West African Institute for Oil Palm Research; and Mr. T. Menendez of the same Institute in July and December respectively; and Messrs. A. Y. B. Schalk and A. Jourdanne, reclamation engineers from Senegal, in March.

MANAGEMENT AND MAINTENANCE

LAND

The access bund to part of the new area of swamp land was completed, and a series of new rice nurseries prepared along the edge of the swamp.

A fence has been erected along the upland boundary of the station and gates installed at the main entrances.

BUILDINGS

Considerable trouble has been experienced with the air-conditioning units installed in the laboratories last year. A series of major breakdowns has resulted in most of the units being out of action.

An open-sided greenhouse has been put up for experimental culture of rice in buckets, and a small dark-room built, into which rice plants in buckets can be moved to induce early flowering. Extension of the main rice drying floor has been completed.

An old mud building has been demolished and a new permanent office for the Station Manager built. Modifications have been made to the implement shed, part of which is being converted into workshops.

Mosquito-screening of existing permanent professional quarters has been carried out and demolition of the three old ones of mud construction started. New permanent buildings are to be erected on these sites.

SERVICES

An exceptionally long dry season led to a shortage of water at the end of May. Management of the scour valve of the dam has improved the quality of the water in the dry season but there is still discolouration.

There has been no serious breakdown in the electricity supply, though there were a number of minor stoppages during the water shortage.

VEHICLES AND MACHINERY

A new Land Rover was obtained during the year and the old one, which had been suffering a series of breakdowns, was laid up. The Bedford 30-cwt. lorry had heavy use and has been giving a considerable amount of trouble. The launch also has been out of action several times during the year owing to breakdown.

A new International tractor was purchased and put into use and the Ferguson tractor has been laid up for overhaul.

A power driven sawbench and some workshop equipment have been obtained.

EXTENSION AREAS

Experiments continue to be carried out on four extension areas—at Mando, Kontobe, Torma Bum and Wellington. In addition, a small piece of upland regrowth bush was temporarily leased for experimental work. Rest houses are maintained at Kontobe, Torma Bum and Wellington.

WEATHER

This year was marked by a very long and severe dry season. The mean minimum temperature in January was the lowest on record, due to prolonged harmattan. Two showers in April brought promise of the rainy season, but not until the end of May did the rains begin in earnest. From then on weather followed the usual pattern, the rains finally ceasing in mid November, though rainfall in August and September was above average. A fall of 7 inches on 2nd August is the highest recorded fall in 24 hours, and this itself was a continuation of the same storm that brought 4.3 inches in the previous recording day. Full meteorological records for the year are given in Appendix A.

AGRONOMY

There has been no change in the general field procedure, which was summarized in the 1959 Annual Report.

The experiment reported last year which compared the effect on yield of leaving rice seedlings for different times in nurseries of different fertilities was repeated with very similar results. The same two varieties were used, and this year the maincrop rice Radin China 4 gave significantly higher yields than the early variety B.G.79. There was no significant interaction between variety and treatment however, and the figures shown in Table 1 are the means of yields of both varieties. These confirm last year's experiment and earlier observations that yield is correlated with the growth of the seedling at transplanting and that a short period at high fertility gives the best results.

TABLE 1

Time in nursery and fertility

Layout 3^2 x 2 factorial with 3 replications.
Treatments 25, 45 and 65 days in nurseries at three levels of fertility.
Varieties B.G. 79 and Radin China 4.
Plots 20 × 20 feet.
Area of plot harvested ·00918 acre.

Yields in lb./acre

Time in days / *Fertility*	25	45	65	*Mean*
	Critical Difference	5%	338	*C.D.*5% 195
		1%	458	
Low	1860	2270	1880	2030
Medium	1880	1960	1480	1780
High	2480	1850	1750	1970
Mean	2070	2030	1700	1930
	Critical Difference	5%	195	
		1%	263	

Coefficient of Variation 14·9%

A double cropping experiment was also carried out on the same lines as last year but, owing to the very severe dry season, there had been insufficient wash of salt from the soil for the first plantings and much of the early crop failed.

There is a very considerable fertility gradient on the farm, from the more fertile former mangrove soils near the river to the less fertile land near the upland which was formerly under *Raphia* palm and sedge growth. Observations in the past had indicated that on this latter type of soil only late maturing varieties gave good yields. Duplicate experiments were thus laid down with early, maincrop and late varieties on both types of land, to determine the yield differences of varieties under the two fertility levels and whether the order of yield was the same in both trials. The site chosen for the trials on fertile land was near the river on land adjacent to the newly laid out access bund and, although the trial gave significant results, yields were poor due to extremely heavy flooding from the river in the early stages of growth. There was no significance shown in the other trial due to poor soil uniformity. It was thus not possible to compare yields between the two trials, but it was noted that in both trials the highest four yielders were the same varieties (one late and three maincrop).

The area under multiplication has been further reduced as experimental work is expanded. Yields in general were good and 175 bushels (of 60 lb. weight) of pure seed were produced and distributed. The Genetic Stock system of maintaining purity of the Standard Varieties has continued.

The small polder which is irrigated from the deep water tank was again in use during the dry season for observation plots of varieties suitable for growing out of season.

BOTANICAL RESEARCH

There have been no new lines of research started during the year, except that full scale experiments on the effect of controlled light and temperature in the growth chambers have been begun. Work on the improvement of varieties, both swamp and upland, for West African conditions has continued and a number of very promising varieties are under trial. Further work has been carried out on post-harvest treatments to improve milling quality and on problems associated with the germination of rice seed.

INTRODUCTION AND TESTING OF RICE VARIETIES

Thirty-eight rices were introduced from overseas during the year and added to the collection. A list of these is given in Appendix B. A further six local swamp rices were also collected. A number of rices were discarded and the West African Rice Varietal Collection now numbers 540 of which 360 were grown under observation in the field during the year and seed of the remaining 180 stored under controlled temperature and humidity.

Thirty-two upland rices are also maintained. Of these, twenty were grown in observation plots this year and the other twelve put into trials.

Requests continue to be received from other countries for seed of varieties from the collection, and the following were sent out during the year:

To Ghana	6 samples
To Gambia	10 samples
To Mali	3 samples
To Guinea	35 samples

To Egypt	4 samples
To France	4 samples
To Surinam	1 sample
To India	1 sample
To East Pakistan	4 samples
To Malaya	4 samples
To Sarawak	35 samples
To Philippines	39 samples
To Taiwan	3 samples
To Korea	4 samples
To Japan	5 samples

Upland Rices

Further investigations have been carried out on yields of the varieties available. Twelve varieties were chosen from observation of their growth last year and two yield trials were laid down on a uniform site selected within a local farmer's upland farm after brushing and burning were completed. This careful site selection was rewarded by reduced coefficients of variation and substantial significant yield differences were exposed. The results of these trials are shown in Tables 2 and 3. In the first trial Anethoda significantly outyielded all other varieties and both VI 28061

TABLE 2

Yield trial of upland varieties (1)

Layout 6 × 6 Latin square.
Plots 10 × 15 feet broadcast at a rate of 60 lb./acre of seed.
Area of plot harvested ·0034 acre.

Variety	*Origin*	*Mean Yield in lb./acre*
Anethoda	India	1120
VI 28061	Ceylon	860
Allagollawa	Ceylon	840
Azucena	Phillipines	680
Gortui	Sierra Leone	540
Kpa Wui	Sierra Leone	530
Critical difference (5%)		186
Critical difference (1%)		255
Coefficient of variation		20·0%

TABLE 3

Yield trial of upland varieties (2)

Layout 6 × 6 Latin square.
Plots 10 × 15 feet broadcast at a rate of 60 lb./acre of seed.
Area of plot harvested ·0034 acre.

Variety	*Origin*	*Mean Yield in lb./acre*
MLYC × VI 283	Ceylon	1050
Tikiri Samba	Ceylon	850
Manyoli B	Sierra Leone	840
Gbengbete 223	Sierra Leone	810
Joboi	Sierra Leone	650
Ca/446/b/33121	Congo	440
Critical difference (5%)		293
Critical difference (1%)		400
Coefficient of variation		32·0%

and Allagollawa significantly outyielded the two Sierra Leone varieties. In the second trial Ca/446/b/33121 had a significantly lower yield than all others except Joboi, and MLYC × VI 283 showed significant superiority over the two lowest yielders.

Promising Swamp Varieties

Yields were in general better than last year though only one variety, Radin China 4 (from Malaya) gave over 3,000 lb. per acre. This is a recovery of its earlier performance, though in the last two years its yields had dropped and were not outstanding though reasonable good. Two other varieties, HR 8 (from Hyderabad) and Gantang (from North Borneo) have behaved in a similar way and this year have again given good yields. Radin Siak 34 (from Malaya) had a good yield for the fifth year running. Cadung Phen R 92 and Bong Sen Den 2 R 10 (both from South Viet Nam) have now been grown for four years and have given good yields in three of them, in both cases the lower yield being when they were grown on the less fertile area. Mas 2401 (from Java) again gave a good yield on more fertile land though in the past its performance has been erratic. Haji Haroun (from Malaya) and India pa lil 46 (local selection) have in the past not given outstanding yields in this collection, but this year had surprisingly high yields. Sokotera (from Zanzibar), which has given outstandingly good yields for four years, was this year disappointing though being on the area of higher fertility. Ecombouka (from Cameroons) and SR 26 (form Orissa) which gave good yields last year have fallen back again this year. Six varieties grown for the first time in the Promising Variety Collection gave very good yields. These are Babo Thi (from Veit Nam), Nam Dawk Mai (from Thailand), Krachek Chap (from Indo-China), Acheh Puteh (from Malaya), Birado (from Guinea) and Vicco (a selection made by a local farmer). The varieties in this collection were as usual grown on long narrow plots of about one-twelfth of an acre.

Two yield trials were laid down on mangrove land at Rokupr this year. The first compared nine early promising varieties. Results are shown in Table 4. As in a similar trial last year, SR 26 and Sokotera came first and second in yield and gave yields significantly higher than the standard varieties D 99, B.G.79 and Lead.

TABLE 4

Yield trial of early promising varieties

Layout Balanced lattice 4 replications.
Plots 10 × 10 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0023 acre.

Variety	*Mean Yield in lb./acre*
SR 26	2890
Sokotera	2730
D 99	2590
Faya	2490
Ecombouka	2490
Haji Haroun	2440
HR 8	2370
B.G.79	2220
Lead	2100
Critical difference (5%)	123
Critical difference (1%)	131
Coefficient of variation	6·0%

The second trial compared 25 varieties. These consisted of eight late and seventeen maincrop rices and the results, which are shown in Table 5 have been divided into these two groups. Of the late varieties, the standard variety India pa lil 46 gave a significantly lower yield than any other and the highest four yielders gave significantly higher yields than the other standard variety Kav. 12. Among the maincrop rices all except Bambako gave significantly higher yields than the standard variety Toma 112. None however was significantly better than the recently released Radin China 4.

TABLE 5

Yield trial of maincrop and late promising varieties

Layout Balanced lattice 4 replications.
Plots 10 × 10 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0023 acre.

Variety	*Mean Yield in lb./acre*
Late varieties	
Raminad	4100
Bong Sen Den 2 R 10	3900
Nam Dawk Mai	3760
Gantang	3730
Nachin 11	3650
Vicco	3560
Kav. 12	3400
India pa lil 46	3060
Maincrop varieties	
Krachek Chap	3730
Neang Chok	3640
Parn A–191	3630
Babo Thi	3590
Khao Tod Lawng	3530
Radin China 4	3520
Mas 2401	3470
Mayang Ebos 80	3440
Birado	3410
Chankong Kras	3330
Sambegeury	3290
Radin Siak 34	3260
Malefike	3210
Ngasein Thidat	3170
Mas 1900	3120
Bambako	2950
Toma 112	2760
Critical difference (5%)	330
Critical difference (1%)	440
Coefficient of variation	8·5%

Three varietal yield trials were carried out on non-mangrove land on station extension areas. At Mando, on riverain grassland, the trial of late maincrop varieties which last year failed to show significance was repeated. Results are shown in Table 6. Radin China 4, which has been released for use in this area, had a significantly higher yield than three of the other varieties in the trial, as did also Cadung Phen R 92.

TABLE 6

Yield trial of late maincrop varieties – Mando

Layout 6 × 6 Latin square.
Plots 12·5 × 12·5 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0023 acre.

Variety	*Mean Yield in lb./acre*
Cadung Phen R 92	1788
Radin China 4	1714
Mayang Ebos 80	1557
Seri Raja	1335
Pai Gazo	1298
Bong Sen Den 2 R 10	1265
Critical difference (5%)	275
Critical difference (1%)	375
Coefficient of variation	15·3%

At Kontobe, on the inland riverain flood plains, the trial carried out last year was repeated on the same three sites, with very similar results. Haji Haroun and Nachin 11 have again given the best yields. These two varieties were provisionally released for this type of land last year. Results are shown in Table 7.

TABLE 7

Yield trial of early varieties – Kontobe

Layout 6 × 6 Latin square.
Plots 12 × 12 feet broadcast at a rate of 40 lb./acre of seed. 2 cwt./acre sulphate of ammonia and 1½ cwt./acre superphosphate applied.
Area of plot harvested ·0023 acre.
Replications: I Deep flooding area.
II Shallow flooding area.
III Shallow flooding area with supplementary irrigation.

Variety	*Mean Yield in lb./acre*		
	Rep. I	*Rep. II*	*Rep. III*
Haji Haroun	1426	540	1271
Nachin 11	2161	1149	1144
Toma 112	1081	785	1003
Radin Siak 34	640	445	999
Sokotera	508	486	990
Parn A–191	1289	735	640
Critical difference (5%)	536	317	305
Critical difference (1%)	731	432	—
Coefficient of variation	38%	38%	25%

The best varieties of floating rices from the successful observation plots grown in 1960 were put into a yield trial on deep-flooding land at Torma Bum. Results are shown in Table 8. The good performance of Indochine Blanc, which significantly outyielded Champa 133 and I.C.53 × I.C.25 (3) in this trial, was repeated in observation plots and confirmed its 1960 promise. Dry conditions after sowing favoured severe attacks of *Helminthosporium oryzae* which killed patches of plants and reduced tillering in many varieties. Fortunately several of the recent introductions were unaffected and appear immune. Mbagboli selections, the Indo-China 53 × 24 lines, and many of the local varieties were badly attacked and a general survey of the area suggested that in years with a dry April and

May the disease is a limiting factor and resistance to it is of prime importance. Observation plots of the remainder of the collection of floating rices were grown, and spaced plant rows of the most promising varieties were sown and reselected to supply nucleus seed for 1963. A second trials ground on even more severely flooding land on the Waanje river was selected for future trials. Further observations on these floating rices were made in the deep water tank at Rokupr and results from these correlate well with the field results from Torma Bum.

Milling Experiments

Investigations have proceeded on the effect of drying after parboiling on milling quality, in particular the speeding of the drying process using fast moving air at lower temperatures. This work continues and will be fully reported at a later date.

The 1959 Annual Report gave the results of experiments which showed that harvesting up to ten days earlier than the accepted time would give a crop with fewer cracked grains and—as judged by the 100-grain weight —with little reduction in yield. An experiment was laid down this year to confirm this and to discover how soon after modal flowering harvesting could be carried out without loss of yield. The experiment was laid down after flowering on a block of rice being multiplied for seed purposes, so that the period from flowering to harvest could be synchronised with the low afternoon humidities and night dews of the harmattan period when cracking of the grain is at a maximum, and so that the effect of early harvesting on yield expressed as the out-turn of whole grains could be seen. At harvest the grain from one plot of each harvesting was shade-dried to 12 to 13 per cent moisture content (of wet grain) before milling to ensure that the milling results reflected cracking in the field and not cracking during post-harvest drying. Results are shown in Table 9. On the usual criteria the normal harvesting date was January 8th, and these results confirm the indications from the earlier experiment that there is no significant fall in yield from harvesting up to nine days earlier than this, and that harvesting six days or more earlier has materially reduced the cracking of the grain. It would appear that the highest yield of whole grains from a crop is produced by harvesting between six and nine days earlier than the usually accepted time—25 to 28 days after modal flowering.

TABLE 8

Yield trial of floating rices – Torma Bum

Layout Randomized block 7 replications (restricted randomization).
Plots 30 × 12 feet broadcast at a rate of 60 lb./acre of seed on 8th April.
Area of plot harvested ·00826 acre.

Variety	*Mean Yield in lb./acre*
Indochine Blanc	2180
Indochine C	2060
Kod Phom	1860
Kailundo (Tisei)	1850
Champa 133	1490
I.C. 53 × I.C.24 (3)	1470
Critical difference (5%)	438
Critical difference (1%)	591
Coefficient of variation	22·0%

TABLE 9

Effect of early harvesting on grain cracking

Layout 6 × 6 Latin square.
Variety India pa lil 46.
Plots 20 × 20 feet planted random fashion at about 6 – 8 inch spacing.
Area of plot harvested .092 acre.

Date of harvest	*Days after modal flowering*	*Mean Yield in lb./acre*	*Whole grains as % of paddy*	*Whole grain recovery in lb./acre*
December 27	22	1580	59	924
December 30	25	1875	57	1063
January 2	28	1922	58	1109
January 5	31	2049	50	1031
January 8	34	1992	52	1028
January 11	37	2075	47	977
Critical difference (5%)		288		
Coefficient of variation		12·5%		

SELECTION OF IMPROVED RICES

Selection has been made among the upland rices. It is expected that this work will proceed quickly as two generations per year will be grown.

Further observations were made on the reselections of promising varieties made last year, and 16 strains of Pindosein A29-20, 41 of Anak Didek and 22 of Nachin 11 were retained.

The remaining reselections of Ngasein 57 were put into a yield trial this year and compared with Radin China 4 and unselected Ngasein 57. Results are shown in Table 10. The coefficient of variation was rather high and significance was only shown in that one reselection had a lower yield than three of the others and than the unselected stock.

TABLE 10

Yield trial of Ngasein reselections

Layout Balanced lattice 4 replications.
Plots 12 × 12 feet planted at measured 6 inch spacing 2 plants per stand.
Area of plot harvested ·0023 acre.

Variety	*Mean Yield in lb./acre*
Ngasein 57 unselected	3130
Ngasein 57/10	2900
Ngasein 57/2	2880
Ngasein 57/60	2850
Ngasein 57/88	2700
Ngasein 57/46	2670
Radin China 4	2600
Ngasein 57/100	2580
Ngasein 57/99	2200
Critical difference (5%)	569
Critical difference (1%)	789
Coefficient of variation	14·0%

HYBRIDIZATION

It may be of interest to review the main ecological conditions for rice growing in West Africa to which the hybridization programme is geared.

So called maincrop varieties of $5\frac{1}{2}$ to $6\frac{1}{2}$ months duration are grown on up-river mangrove lands in Sierra Leone and Gambia and on shallow flooding sites on the southern grasslands of Sierra Leone. These varieties are also the mainstay of inland valley swamp cultivation in Sierra Leone and of similar habitats to all these in Liberia and Guinea. Early, $4\frac{1}{2}$ to $5\frac{1}{2}$, month varieties are grown on sea-water affected mangrove land where there is a limited growing season and on more briefly flooded swamps in Sierra Leone. These are the most common varieties in Nigeria, where B.G.79 is widely grown on non-irrigated lowlands, and are also important in Ghana, represented by D 99 and latterly by D 52-37. Very early, $3\frac{1}{2}$ to $4\frac{1}{2}$ month, varieties will be needed on irrigation schemes such as those envisaged on the Accra plains, where two to three crops a year are possible, and on dam sites where an alternative second crop is planted. Mangrove soil empoldering schemes relying initially upon rain-fed conditions may also make use of these varieties. Upland varieties of 100 to 120 days duration are grown all over West Africa. Long duration floating rices are grown in the deep flooding southern grasslands of Sierra Leone, in Guinea, and extensively in Northern Nigeria.

No changes have been made in the breeding techniques adopted, whereby actual hybridization is carried out in the dry season.

Maincrop varieties

About seventy F_1 plants, representing twenty crosses between eleven parents, were harvested at the beginning of the year, having been grown in the dry season and induced to flower by short day treatments. These were sown as individual plots and a few selfs undetected in the F_1 were removed at harvest. Exceptional hybrid vigour and considerable transgressive segregation for yield were apparently present in three lines, Nachin 11 × Sokotera, Seri Raja × Gantang and Mayang Ebos 80 × Seri Raja. In general, normal F_2 selection was adopted, poor plants only being discarded. Single plant selections showing strong transgression for earliness were retained from several lines. Excellent single plant selections were retained from three lines as part of a detailed programme to test the comparative efficiency of various selection methods in rice.

Early varieties

Selection of the F_3 progenies of crosses between B.G.79, Lead, Faya and HR 5 was carried out. Some experiments into the effectiveness of stringent seedling selection were made on this material and these suggested that phenotypic nursery effects and such genotypic defects as are exposed in the nursery can be largely eliminated, thus reducing the population for selection in the field and cutting down competition effects due to small plants. Some of this material shows considerable promise.

Observations continued on the remaining selections taken from Indian material selected in Malaya to the F_7 generation and then sent to Rokupr. These consist of a number of *japonica* × *indica* crosses with Pe Bi Fun, Norin, Riku and Tai Chu 65 among the *japonica* parents. One of these (Pe Bi Fun × Mayang Ebos 80—52/M/8/1) yielded 80 per cent of Lead in trial, though almost a month earlier. A further introduction of *japonica* × *indica* material from Malaya was made in 1960 and reselected in the F_9 generation in 1961. Some of this material looked outstanding for high yield, tillering, straw strength and earliness and included lines with the Nigerian-favoured B type grain from a cross between Tai Chu 65 and Siam 29. Lines from a Tai Chu 65 × Mayang Ebos 80 cross also looked extremely promising. Many single plant selections were made and subsamples were under test for photoperiod response at the end of the year.

Very early varieties

Nine lines from this programme were selected in the F_3 generation, none of them showing a great deal of promise. Tests on the lines showed that those which had Tun Sart as a parent had a high proportion of plants with low sensitivity to photoperiod. Several more crosses were attempted using Patnai 16 as a parent, but resulted in a high proportion of selfed plants. Observations on possible new early parents for this programme continue.

Floating rices

Single plant selections of nine lines of the cross Indo-China 53 × Indo-China 24 were completed at Torma Bum under deep water conditions and will be bulked at Rokupr for final tests in 1963. Though yielding very well they showed some susceptibility to attack by *Helminthosporium* during the dry spell early in 1961. The cross X (56) 3, Toma 112 × Indo-China 53 was discarded as showing little promise.

Some crosses between good floating rices of long duration and Patnai 16, a 110-day Indian Aman variety of low sensitivity to photoperiod, were made to examine the possibility of producing a short duration variety with the floating character. Tests at the end of the year established that eight lines in the F_2 generation were available, and segregating for duration. Varieties with these characters are needed in Northern Nigeria where deep but ephemeral flooding occurs in some places.

Upland rices

Some experimental hybrids between the best upland varieties and some excellent four to five-month swamp varieties were made to test the effectiveness of this method of breeding. The F_1 and F_2 generations of these crosses will be grown in 1962.

Interspecific hybrids

A new hybrid between Patnai 16 and Legbeh, an upland variety of *Oryza glaberrima*, was made and the F_1 plants were under study. The F_1 once more exhibited complete pollen failure and set no seed. Some new attempts were started to induce amphidiploids in this material, which is very favourable to such studies due to its rapid maturation and low sensitivity to photoperiod.

PHYSIOLOGICAL WORK

Successional sowing experiments have been continued in the field at Rokupr and at other sites in West Africa to observe the effects on yield and duration. At the same time the first series of experiments have been carried out in the growth chambers comparing growth of three varieties under five photoperiods and two temperature regimes. Some further experiments on dormancy and viability have also been carried out, and some field observations made on salt tolerance.

Factors influencing Duration and Yield

The successional sowing experiment carried out at several latitudes between 5 and 13 degrees North was repeated this year at Sapu in the Gambia, Badeggi in Nigeria and Nungua in Ghana, as well as at Rokupr. It is very difficult to interpret the results, now obtained over several years, partly due to the fact that, owing to local conditions, it was not possible to standardize the cultural methods at each station. The general picture is however that, especially with the early sowings in April, the higher the

latitude the longer the duration of the rice. As the sowings get later to October there is a decrease in duration in all cases, though this is more marked in the high latitudes than in the low ones. In Malaya, Dore has reported that between latitudes 3 and 5 degrees North, the higher latitude has a shorter duration.

A further series of trials to examine the effect of sowing date on yield was carried out at Rokupr. Two trials were badly damaged by heavy flood and, of the remainder, only one gave significant results; these are shown in Table 11. The highest yield has again been from the sowing on 18th June; this has been so in all the experiments carried out over the past years which have shown significant results, and these have included early, maincrop and late varieties.

The general conclusion from this series of experiments is that, at Rokupr, with *indica* varieties sown within the normal season from June to August, yield increases to a maximum when the rice is sown about the 18th June and thereafter falls. There are indications that the slope of increase in yield up to the maximum may be less than that of fall in yield later. There appears often to be a minor peak in yield with later sowings, though this is variable in date and it is thought may possibly be due to variable weather factors: the main peak is constant in date which suggests it is due to a constant factor such as photoperiod. This fall in yield on late planting of varieties sensitive to photoperiod stresses the importance of producing non-sensitive varieties for areas where late planting cannot be avoided.

TABLE 11

Effect of sowing date on yield — Gantang

Layout 6 × 6 Latin square.
Plots 15 × 15 feet planted at measured 6 inch spacing 2 plants per stand
Area of plot harvested ·0038 acre.

Sowing date	*Mean Yield in lb./acre*
June 18th	1906
July 2nd	1868
June 4th	1865
July 16th	1530
July 30th	1530
August 13th	1252
Critical difference (5%)	247
Critical difference (1%)	337
Coefficient of variation	12·0%

The first experiment in the growth chambers has now been completed after 348 days continuous running. Since it was anticipated that a number of unforeseen technical difficulties would arise during the initial period of use, it was expected that the experiment might resolve itself into an exercise in the operation of the chambers. In fact a number of difficulties did arise but most of these were overcome and some useful results were obtained. The main difficulty was that one 2-horse-power air-conditioning unit was found to provide insufficient cooling. This influenced the design of the experiment which was run at temperatures a few degrees higher than was originally intended, as follows. Five replicate buckets (single plants) of three varieties were grown under five photoperiods (8, 10, 11, 12 and 14 hours) in a temperature regime of 37°C for the first eight hours of

"day" and at 27°C during the remainder of the 24-hour cycle; all these treatments were repeated in another five chambers except that the temperature was maintained at 37°C continuously. The second half of the experiment was abandoned soon after the beginning since all the plants kept continuously at 37°C died within a few weeks.

The main lighting in each chamber was supplied by eight, 5-foot, 80-watt, "white" fluorescent tubes with internal reflectors which provided a light intensity of about 9,000 lux at the level of the top of the plants, which was kept at about 9 inches from the ceiling of the growth compartments; this light intensity dropped to about 7,000 lux for the plants in the extreme corners of the chambers. Supplementary light was provided in each chamber by four 25-watt incandescent bulbs which gave a light intensity varying between 200 and 500 lux depending on the position in the chamber. The main lighting was given for the first eight hours of each "day"; the supplementary light was given for six hours, but it was switched on at different times in each chamber so that it overlapped with the main lighting to various extents to give the range of photoperiods listed above. Thus, although the photoperiod varied between treatments, the total radiation per day received by the plants was the same.

The varieties chosen for investigation were some which have been studied intensively in the field at Rokupr and elsewhere in West Africa in the successional sowing experiments: Radin China 4 (from Malaya), Lead 35 (a Rokupr selection from material derived from British Guiana) and Tai Chu 65 (from Formosa). The first two varieties belong to the *indica* sub-species and the last is said variously to belong to the *japonica*, sub-*japonica* or *indo-japonica* group. The seeds were set to germinate in petri dishes in the dark at 32°C for seven days, then transferred to the buckets under natural conditions for a further 7 days, after which the buckets were placed in the chambers. (Recent work by R. Best has indicated that rice is not sensitive to photoperiod during these early stages.)

A summary of the results is given in Table 12. It will be seen that Tai Chu 65 is the least sensitive to photoperiod in this experiment, but that, even with this variety which has the reputation of being completely insensitive, a delay in flowering occurred under a 14-hour photoperiod. In the case of the other two varieties minimum duration occurred in the 10-hour photoperiod. It will also be noted that for these two sensitive varieties there was maximum uniformity amongst the plants at 10 hours; the increase in variability if the photoperiod was either increased or decreased from this value was quite marked. From the results of successional sowing experiments in the field, it was noted in the 1956 Annual Report that the time of planting is important, not only with regard to the duration of the crop (as measured by the period to modal flowering), but it also affects the plant-to-plant variability in time of flowering: when the rice was planted so that it was reaching maturity in long days the variability was most marked. The results of this present experiment suggest that this variability noted in the field is associated directly with photoperiod response.

Another interesting comparison between the results in the chambers and those in the field is that of the relative durations of Radin China 4 and Lead 35. The records of the successional sowing experiments at various latitudes show that, for any given sowing date, Lead 35 always flowers before Radin China 4. It will be seen that in every treatment in which the varieties flowered in the chambers the reverse is true. This comparison of results convincingly demonstrates that some other factor—in this case possibly temperature—also affects duration; furthermore it is evident that there are considerable varietal differences in response to this other factor as well as to photoperiod.

TABLE 12

The effect of photoperiod on the varieties Tai Chu 65, Lead 35 and Radin China 4 grown under constant daily amounts of light radiation.

Photoperiod in hours	*Variety*	*Number of plants*	*Mean duration (period to heading) in days (with standard error)*	*Coefficient of variation (with standard error)*
8	T.C.65	4	149 ± 10·4	13·9 ± 4·9
	L. 35	3	157 ± 38·6	42·4 ± 17·3
	R.C. 4	5	107 ± 6·9	14·4 ± 4·6
10	T.C.65	5	134 ± 8·1	13·5 ± 4·3
	L. 35	5	95 ± 3·8	9·0 ± 2·8
	R.C. 4	3	76 ± 1·7	3·8 ± 1·6
11	T.C.65	5	151 ± 16·2	24·0 ± 7·6
	L. 35	4	133 ± 14·3	21·5 ± 7·6
	R.C. 4	4	111 ± 6·1	11·0 ± 3·9
12	T.C.65	4	137 ± 11·1	16·2 ± 5·7
	L. 35	5	>348*	
	R.C. 4	1	159	
14	T.C.65	5	191 ± 11·1	13·0 ± 4·1
	L. 35	5	>348**	
	R.C. 4	4	>348**	

Note: Any plant which had not flowered by the end of the experiment was said to have a duration of greater than 348 days (on transfer to 10½-hour photoperiods at the end of the experiment all plants headed in 30–32 days).

*One plant 215 days; the remainder more than 348 days.

**All plants more than 348 days.

From the point of view of breeding varieties insensitive to photoperiod suitable for West African conditions, the present results suggest that Tai Chu 65 is promising parental material since it is practically insensitive to a range of photoperiods extending over those to be found in West Africa. This confirms the indications of previous successional sowing experiments. From the genetical point of view it has been shown from breeding work carried out on this station and elsewhere that Tai Chu 65 is one of the few varieties of *japonica* type which produces fertile hybrids when crossed with large numbers of *indica* varieties.

With the addition of another air-conditioning unit to the growth chamber laboratory, it is hoped next to investigate the effect of temperature and its interaction with photoperiod on growth and duration.

Dormancy and Viability of Rice Seed

In the literature on seed storage there are many suggestions that marked differences may be found in the longevity of different rice varieties. But in many cases the observations can be criticised on the grounds that little attempt was made to ensure that the different varieties being studied were stored under identical conditions. In the last Annual Report some equations were given for predicting percentage germination of the variety Toma 112 after storage for any given period under constant environmental conditions. In order to assess the extent to which these equations could be used as a guide to the storage of other rice varieties it was necessary to compare the germination of a number of varieties over a period of time when stored under closely controlled and identical conditions.

For this investigation six varieties were chosen which not only represent a wide range of genotypes but whose seed is easily distinguishable either because of colour or morphological differences: these were Radin China 4 (from Malaya), Madagascar 1303 (from Madagascar), Kayangya D402 (from Burma), Tai Chu 65 (from Formosa), Tai Chu 122 (from Formosa) and Masalaci (from Nigeria): the first five are members of the *sativa* species, Radin China 4 and Madagascar 1303 being in the *indica* group and the other three in the *japonica* group; the last variety is a mass selection of a floating type of the *glaberrima* species. Seed from these varieties was sun-dried to a little under 11 per cent moisture content immediately after harvest and then stored for a few weeks in a refrigerator at about 3°C until the experiment was ready to begin. Previous work has shown that the rate of the processes leading to loss of viability will have been negligible under these conditions. The seed of the different varieties was then thoroughly mixed and brought to 12.5 per cent moisture content. After this it was divided into batches and stored in sealed glass ampoules in an incubator at 27°C. The incubator was kept in an air-conditioned room but unfortunately the air-conditioner broke down on a number of occasions so that the temperature in the incubator rose to about 30-33°C for several periods of varying length. The results of germination tests showed that there were no significant differences between the half-viability periods of the six varieties stored under these conditions: the values were, in order of the varieties listed before, 175, 179, 182, 176, 175 and 176 days. It would thus appear that, although differences between varieties may exist, they are in general very small and the equations given previously may be used with reasonable confidence for designing storage conditions for most rice varieties.

It has often been suggested that there is a correlation between dormancy and viability, i.e., that a variety which shows pronounced dormancy will last longer than one which has little dormancy. The last experiment has also served to show that this is not so since the varieties used have markedly different dormancy periods: Tai Chu 65 for instance showed 90 per cent germination at harvest whereas it took Masalaci about 100 days to achieve 50 per cent germination.

Investigations have continued into the mechanism of seed dormancy. There are indications that, within the limits of experimental accuracy, the temperature coefficient for rate of loss of dormancy is the same in all the varieties so far examined. Further work will be necessary to confirm this and the investigation is to be extended to a few more varieties. The equation which describes the relationship between storage temperature and dormancy is as follows: $\log d = K_d - C_d t$, where d = mean dormancy period (time taken for germination to reach 50 per cent), t = temperature in degrees Centigrade, and K_d and C_d are constants. At present it would appear that C_d is the same for all varieties and has a value of about 0·053, which represents a Q_{10} of about 3·38 for rate of loss of dormancy. If this value is the same in all rice varieties it suggests that the same dormancy mechanism operates in all cases—this would include varieties of the *glaberrima* species were dormancy is normally much more pronounced. The difference of degree of dormancy shown by the different varieties is resolved into the varying value of K_d which is only constant for a particular variety.

Translated into practical terms this means that although varieties may differ markedly in their mean dormancy period at ambient temperature (e.g., an experiment showed a nine day difference between Madagascar 1303 and Radin China 4 at 27°C), the differences at higher temperatures are much smaller (e.g., a one-day difference was found

between the same varieties at 37°C). This is one of the reasons which makes the heat treatment previously suggested in the 1959 Annual Report particularly suitable as a practical method of breaking dormancy in a wide variety of breeding material. Because of their generally more pronounced dormancy, it is now suggested however that for the *glaberrima* species the period of treatment at 47°C should be extended to 14 days.

Further experiments have now been carried out on the effect of various biologically active substances on dormancy. For convenience these may be divided into experiments concerned with organic growth substances, respiratory inhibitors, sulphydryl and related compounds, oxidizing agents, inorganic ions, and acidity (pH). The substances investigated have been listed under these heads below; however, although each substance is mentioned under a single head only, it should be realised that this is a somewhat arbitrary division since some substances could qualify for inclusion under two or more categories. In most cases two methods of application were tried: in the first method seeds were steeped for 24 hours in a solution of the substance under test, dried, then set to germinate in water; in the second method the seeds were set to germinate directly in the solution. In all cases where both methods were tried and the substance found to be active, its effect was shown by both methods of application (except in the case of strongly acid solutions which prevented growth if applied during the germination test). All substances were investigated over a range of concentrations and germination tests were carried out on several occasions. The results obtained with a few of the substance listed below were mentioned briefly in the 1959 Annual Report; they are included again here in order to make the present list complete.

Organic growth substances. Under this head a number of plant growth hormones and synthetic physiologically related substances which affect plants in trace amounts are included, and also a number of other substances which can be considered as nutrients metabolized by plants. In a number of cases these substances, or metabolically analagous substances, have been shown to affect the dormancy of other species.

β–indoleacetic acid; naphthalene–1–acetic acid; 1–naphthoxyacetic acid; 2–naphthoxyacetic acid; α–(1–naphthylmethylsulphide)–proprionic acid; 2,3,5–tri–iodobenzoic acid; gibberellic acid by itself and in combination with β–indoleactic acid or naphthalene–1–acetic acid; kinetin (6–furfuryl aminopurine) by itself or in combination with either or both gibberellic acid and β–indoleacetic acid; coumarin; sucrose by itself or in combination with gibberellic acid; dextrose; thiamine, nicotinic acid and pyridoxine–HCl by themselves or in combinations; l–alanine; urea; ethylene; the following organic acids as their sodium salts, succinate, fumarate, hydrogen malate, citrate, pyruvate, oxalate, formate, tartarate, lactate, and acetate; sodium salt of reduced diphosphopyridine nucleotide.

Oxidizing agents

Oxygen; hydrogen peroxide; calcium hypochlorite (bleaching powder); potassium chlorate; potassium dichromate; potassium permanganate. The following substances were included because of their property of acting as hydrogen acceptors in biological systems; methylene blue; 2,3,5–triphenyltetrazolium chloride.

Respiratory inhibitors

Carbon monoxide; sodium azide; potassium cyanide; sodium sulphide; hydrogen sulphide; sodium diethyldithiocarbamate; 2, 3–dimercapto–1–propanol (BAL); 2, 4–dinitrophenol; α, α′–dipyridyl; *o*–phenanthroline; 8–hydroxyquinoline; disodium–ethylenediaminetetra-acetate; hydroxylamine hydrochloride; sodium fluoride; sodium arsenate; sodium arsenite; *p*–chloromercuribenzoate; iodoacetic acid; sodium fluoroacetate; sodium malonate (pH 4).

Sulphydryl and related compounds

Thiourea; oxidised glutathione; reduced glutathione; cystine; cysteine–HCl; sodium thioglycollate.

Inorganic cations

Sodium+; potassium+; ammonium+; magnesium++; manganese++; iron++; iron+++; cobalt++; nickel++; copper++; zinc++; silver++; mercury++.

Inorganic anions

Chloride; sulphate; nitrate; nitrite; molybdate by itself and in combination with nitrate.

pH

A range of pH was investigated from 1·1 to 13·0 using various concentrations of hydrochloric acid and sodium hydroxide, and various dilute buffer solutions. A comparison was also made between hydrochloric acid, sulphuric acid, nitric acid (all at equal pH) and nitrate (at approximately equivalent normality).

Table 13 shows those substances which affected dormancy; the others had either very little or no effect. In those cases where combinations of substances were tried no interactions were shown except in the case of nitrate and hydrogen ions where there was evidence of synergism.

TABLE 13

Substances which affect dormancy in rice seed

A plus sign indicates acceleration of loss of dormancy; a minus sign indicates retardation of loss of dormancy. The number of signs gives some indication of the relative effectiveness when used at the optimum concentration in the case of the stimulatory substances, or at 0·01 to 0·001 molar concentrations in the case of the inhibitory substances.

Substance	*Approximate optimum molar concentration in steeping method (where appropriate)*	*Activity*
oxygen*		+ +
hydrogen peroxide	1·00	+ + + + +
nitrate	0·01	+ + + (+)
nitrite	0·01	+ + + +
carbon monoxide* (90% CO + 10% O_2)		+ +
cyanide	0·001	+ + + + +
azide	0·001	+ + + + (+)
hydroxylamine	0·01	+ + + +
sodium sulphide	0·01	+ +
hydrogen sulphide	0·1	+ + +
giberellic acid	0·001	+ + (+)
kinetin	0·001	+
methylene blue	0·001	(+)
pH 2·0**		+
pH 1·5**		+ +
pH 1·1**		+ + + +
pH 12·0**		—
pH 13·0**		— —
copper++		— —
silver++		— — —
mercury++		— — —
p–chloromercuribenzoate		— — —
coumarin		—

*A comparison of these substances with the others is not strictly valid since they were applied as a gas.

**Results refer to the steeping method only. Seed will not germinate in solutions of these pH values.

The work will be discussed more fully in a separate publication; it will be sufficient here to underline the main points of interest. Considered in conjunction with the work on dormancy mentioned in previous Annual Reports, it would appear that some oxidation reaction speeds up the breaking of dormancy. Of the oxidizing agents tried only certain ones were

effective, i.e., oxygen and hydrogen peroxide. Although nitrate and nitrite are not normally considered as oxidizing agents they could be included in this list for the present purpose since they can function as hydrogen acceptors in many biological systems. Methylene blue, which caused a very slight stimulation, might also be included in this list for the same reason. It is possible that the large stimulation caused by hydrogen peroxide as compared with oxygen is due to the fact that it provides an efficient method of introducing comparatively high concentrations of oxygen into the seed tissue since there is evidence that the hydrogen peroxide is largely enzymically decomposed to evolve oxygen in the tissues. Since the only oxidizing agents which are effective are those which can act as hydrogen acceptors in the terminal oxidation of repiration, it might be supposed that the oxidation reaction involved in the breaking of dormancy is associated with respiration. However there are two main lines of evidence which suggest that this is not so; first, the temperature coefficient for rate of loss of dormancy is higher than is usual for rate of respiration; secondly, a marked *stimulation* in breaking dormancy is caused by a number of inhibitors which are relatively specific for the enzymes of respiratory terminal oxidation, i.e., carbon monoxide, cyanide, azide, hydroxylamine, and sulphide.

A possible hypothesis for the dormancy mechanism is as follows. It is necessary for some oxidation reaction (probably non-enzymatic on the evidence of temperature coefficients) to occur in newly harvested seed before germination can occur. The covering structures are relatively impermeable to gaseous oxygen so that there is normally a low oxygen tension within the seed. The oxygen tension may be increased by removing part of the covering structures, by increasing the oxygen pressure surrounding the seed so that the rate of diffusion inwards is increased, or by introducing oxygen by allowing hydrogen peroxide to be absorbed. Within the seed oxygen is not only used for the oxidation reaction leading to the loss of dormancy, but the small amount available is also competed for by the enzyme(s) of respiratory terminal oxidation; the introduction of respiratory inhibitors or alternative hydrogen acceptors to oxygen (e.g., nitrate and nitrite) might decrease dormancy by virtue of decreasing the competition for oxygen and thus making more available for the breaking of dormancy. It would appear that nitrate, nitrite and hydroxylamine do not stimulate germination in some way connected with nitrogen nutrition since the ammonium ion, urea and various amino-acids were shown to have no effect on dormancy.

The increase in rate of loss of dormancy with increase in temperature might be explained in terms of increasing the rate of the oxidation reaction. Alternatively, temperature might affect some chemical reaction which opens up an alternative metabolic route to germination. Although it is still believed that the method of heat treatment, which was described in the 1959 Annual Report, is the most efficient and convenient practical method for breaking dormancy, the results described here do suggest alternative methods which may be of use in some cases. Because of their high toxicity to man it is not suggested that respiratory inhibitors should be used, even though these substances are very effective. Pre-soaking for 24 hours in a 0·1 normal solution of nitric acid (there is significantly less response when 12 or 48 hour periods of soaking are used) or hydrogen peroxide, followed by drying before setting to germinate, is probably the best alternative method. Nitric acid is superior to any other acid since both the hydrogen and nitrate ions are stimulatory and there is some evidence of synergism between them. It should be pointed out however that neither method has been tried on a large number of varieties and even on the test variety Toma 112 they do not give 100 per cent germination

when the population of seed shows no germination without treatment. Furthermore, these methods are relatively ineffective on strongly dormant *glaberrima* varieties.

Salt Tolerance of Rice Varieties

The central block of the new Wellington experimental empolder was left under free salt tidal inundation until the end of April and provided an opportunity of testing the collection of reputedly salt tolerant varieties. After the sluices were closed the salt concentration fell slowly due to rain-water leaching, and three successive plantings were made at fortnightly intervals from 1st July onwards. Out of the twenty-five varieties tested, four showed exceptional tolerance, even at the first planting. These were Lead 35, SR 26, Wellington (a local selection) and Bandioulou (from Guinea).

A series of simple bucket tests were carried out which showed excellent correlation with the field results. For each test 11 kilograms of dried sieved soil were used. Eight-and-a-half litres of salt solution of the required strength were prepared and the soil stirred slowly into this. After 24 hours with occasional stirring the surplus liquid was poured off and replaced by a second charge of the same concentration. After a further 24 hours similar treatment with a third charge of salt solution was given; by this time the soil and solution were in equilibrium for the required salt concentration. The pH was adjusted by addition of lime (the amount required being determined by testing a small sample) and nitrogen, phosphorus and potash fertilizers were added to replace the loss of nutrients by leaching and to provide a fertile soil with salt as the main limiting factor for growth. Surplus water was drained off and the soil put in a 10-litre polythene bucket without drainage.

A test of nine varieties at five salt levels showed excellent comparison with the field work. Lead 35, SR 26 and Wellington showed survival and fair growth up to 0·9 per cent salt concentration. The most useful range for separating tolerant from intolerant varieties when transplanted at six weeks of age appears to lie from 1·0 to 0·35 per cent sodium chloride.

DISEASES

There was very little disease apparent during the year. In the nurseries attack by *Piricularia oryzae* was very slight, and *Ephelis pallida* was not seen in the field.

SOIL SCIENCE

Further work on the reclamation of mangrove soils, particularly from the practical aspect, has been carried out, and investigations into other types of rice soils have been expanded and increased.

INVESTIGATIONS INTO TIDAL MANGROVE SOILS

The emphasis of this work has now moved from the laboratory into the field. Laboratory work has consisted of continuation of investigation into sulphur oxidation and fertility of mangrove soils. In the field, the first full trials of reclamation procedure based on previous laboratory work have been carried out, and field experiments have been started in Nigeria on the decomposition of the fibrous mat in the mangrove soils there.

Phosphorus fixation

Last year it was reported that mangrove muds in Sierra Leone contain little aluminium phosphate in spite of a high aluminium content and high

phosphorus-fixing capacity. Recent publications and communications have indicated that this phenomenon is widespread in many different soils. Work has continued in Nigeria and, as in Sierra Leone, a considerable amount of fixed added phosphorus is found not to be recoverable by the Chang and Jackson method. Further investigation has been started. So far it has been found that when the mud is dried some of the iron-bound phosphate is rendered non-extractable in the usual sodium hydroxide reagent. This investigation continues.

Nitrogen immobilization

The fibrous material in mangrove mud contains a high proportion of lignin—over 40 per cent. As lignin is known to be active in immobilization of inorganic nitrogen it was thought that the fibres were mainly responsible for the immobilization of nitrogen in Sierra Leone mangrove soils. Investigations have been carried out on mangrove muds in Nigeria to find the specific part played by the fibre but, contrary to expectations, hardly any nitrogen—only 4 parts per million in 10 weeks—was immobilized by the fibre.

Copper deficiency

It was suspected that a copper deficiency might be limiting yields in newly reclaimed mangrove swamps in Nigeria and some preliminary experiments have been carried out. Up to 10 parts per million of copper as sulphate has been added to mangrove soils and increased growth of rice obtained. Indications are that the effect is enhanced by high levels of nitrogen, potash and phosphorus. More detailed experiments will be carred out.

Field experiments

The experimental empoldering scheme at Wellington has been operated with two alternative methods of reclamation in view: a) the oxidation of soil sulphur compounds by empoldering and drainage followed by the elimination of toxic elements by restoration of tidal conditions; b) the prevention of sulphur oxidation by utilizing tidal flooding for the whole of the dry season. Both methods involve elimination of sea salt by imposing drainage conditions at the onset of the rainy season before rice is planted. In the first method inundation of the land with sea water may be confined to the initial reclamation period, after which tidal wash may be permanently excluded. The second method would involve a permanent regime of seasonal flooding with salt water, and might for this reason be less satisfactory in the long run.

The experimental area consists of three half-acre empolders. One of these was put under drainage conditions (i.e., outflow of drainage water allowed but entry of tidal water prevented) in February 1961 and remained so throughout the year. This empolder is being reserved for future experiments. Another one, treated by the second method listed above, was used for trials of salt tolerant rices reported earlier. The third was used for investigation of the first method of reclamation as follows. At the beginning of April the polder was divided into two blocks. At that time the pH value of the top foot of soil was fairly uniform throughout the polder at about 2·0. One block was isolated from tidal action by the erection of a subsidiary bund. The second block was opened to tidal wash and was inundated with sea water for two months until 5th June. Both blocks were then returned to drainage conditions. At this stage the pH value of the surface soil was much higher, that in the leached block being 3·6 and in the unleached 3·1 (means of 25 random determinations in the field using a portable pH meter and spear electrode). The small difference between

the two treatments may be due to the fact that the "unleached" plot was leached to some extent owing to extremely high tides which overtopped the dividing bund. However, determination of the soil pH value below the top two inches showed that whereas the leached soil had values between 3 and 4, those of the unleached soil were invariably below 3. It may be concluded that leaching with sea water had resulted in a significant elimination of soil acidity. This was particularly noticeable in higher parts of the polder where pH values of between 5 and 6 were reached, and a trial of ridging to help in elimination of acidity might be worth while in the future.

Representative portions of the two blocks were used for statistical experiments in which various applications of lime were made. The lime was applied as a top dressing and no cultivation was carried out at this stage to avoid bringing saline or acid subsoil to the surface. One month after the application of the lime, test seedlings of the variety Lead 35 were planted in diagonal rows across the plots. The survival of these seedlings on the leached plot indicated that sea salt had been eliminated and the experiment was fully planted with new seedlings of the same variety on 4th August.

TABLE 14

Summary of rice yields on freshly reclaimed mangrove soil

Mean yields in lb./acre

	Lime in tons/acre				
	0	*1*	*2*	*3*	*4*
Leached	1780	2180	2230	2190	2260
Not leached	0	560	1690	1510	1820

A summary of the yields from these experiments is given in Table 14. Leaching with tidal water had a beneficial effect on the rice crop and maximum yield was obtained by liming at the rate of one ton per acre, though the yield without lime was satisfactory. In the unleached plot no yield was obtained without liming, most of the seedlings dying shortly after planting. Even with lime, yields were lower, though a satisfactory crop was obtained by liming at the rate of two tons per acre.

Even better yields were obtained from a leached plot on slightly higher ground, where the initial soil pH values were generally over 4·5 and no lime was used. Undoubtedly the first year of the experiment has demonstrated the possibility of eliminating toxic effects by leaching with salt water, though it must be borne in mind that when the rice was harvested considerable reserves of oxidizable sulphur was still present, especially in the subsurface soil. It will be necessary to determine the fate of this in subsequent years and the leaching process may have to be repeated for several years before soil conditions can be stabilized, after which tidal water might be permanently excluded. Meanwhile it is hoped to determine whether the lime applied will have any residual effect. The high oxidizable contents of the soils suggests that this is unlikely. In view of the high yield obtained by leaching in the absence of lime it is probable that applications of lime during the reclamation period would be uneconomic, except possibly in the later stages.

Field experiments have been started in Nigeria to investigate possible methods of decomposing the fibrous mat in mangrove swamp soils. It was hoped to exclude tidal water and thus allow the topsoil to dry out and the organic matter to oxidize. Owing to the amount of fibre in the soil, however, it was found impossible to build impermeable bunds from local

soil and no satisfactory results were obtained. If this method is to be tested it will be necessary to bring soil for the bunds from elsewhere, which would not be practicable on any considerable scale. An alternative method of reclamation must thus be found for areas where this problem occurs.

INVESTIGATIONS INTO THE CHEMISTRY AND FERTILITY OF RICE SOILS

The State of Reduction of Waterlogged Soils

It was stated last year that the definition of "Healthy Reducing Conditions" was insufficiently sensitive to give useful information about normal paddy soils and that optimum reducing conditions were probably a factor of the rate of supply of available nitrogen. Investigations into this have continued. The equation $Eh = K - k.\log Fe^{++} + 3k.pH$ previously determined has been rigorously tested at low pH in pure solutions and found to apply. Approximate tests at low pH in the presence of clay particles indicated that it again applied. The equipment for testing it rigorously in the normal soil pH ranges in the presence of clay particles is not yet perfected.

Since laboratory analyses and bucket tests have shown all soils examined to be low in nitrogen—although it has been difficult to show response to nitrogen fertilizers in the field—and since varying the water regime will radically alter the chemisty of a waterlogged soil, especially that affecting nitrogen availability, a series of bucket experiments have been carried out to test methods and levels of application of sulphate of ammonia under varying water regimes.

In the first series of experiments three different soils were used and superphosphate was added so that the only factor limiting growth was likely to be nitrogen. The soils were placed in buckets and water added so that they were at 25, 30, 50, 70, 80, 90, 95 and 100 per cent water holding capacity, and with one inch and six inches of standing water. In two other treatments, water holding capacity was varied continuously between 100 per cent and 95 and 85 per cent respectively. These conditions were maintained by daily, or as the plants grew large twice daily, weighings and adding water as required. Rice was planted in the buckets after these soil conditions had been maintained for one month.

At planting the available nitrogen in the soils was determined and found to range from 3 to 6 milligrams of nitrogen per 100 grams of soil. After one month, only traces of available nitrogen were found in the buckets where the water content was greater than 80 per cent; rice plants remove nitrogen from the soil as soon as it becomes available. The usual rises in pH that took place after waterlogging were found to be directly related to the release of ferrous iron; this fits in with the theory of the poising effect of ferric iron.

Assuming that nitrogen is the factor limiting growth (for the regimes at or near complete waterlogging), and since ferric iron is the terminal hydrogen acceptor in a waterlogged soil, it would be expected that a low-iron soil would yield best under conditions of less than 100 per cent waterlogging and that a high-iron soil would yield best under standing water—organic matter having to be broken down to release nitrogen. Also that some nitrogen should be lost by denitrification under fluctuating regimes, thus depressing yields. The results bear out these arguments, and also the emphasis that is laid on accurate water control where possible in more advanced rice-growing countries. They also underline the importance of maintaining wet conditions in inland valley swamps in Sierra Leone for successful rice cultivation. Cases of overdrainage and complete loss of fertility have occurred in these swamps in the past.

In the second series of experiments two bucket trials were done, one on levels of applied nitrogen and the second on times of applying nitrogen, both under varying water regimes. The first showed quite definitely that, even with high additions of sulphate of ammonia, nitrogen is rapidly lost and scarcely affects the yields at all in buckets in which the water regime continually fluctuates between waterlogged and partially aerated. It also showed that there is no readily available nitrogen left in the soil under rice one month after adding sulphate of ammonia. The second showed that nitrogen added two months after planting had no effect on yield and that, even with earlier application unless the soil was maintained in a waterlogged condition the effect was negligible. Results of this experiment are shown in Table 15.

From these two experiments it can be concluded that nitrogen should be well dug into the soil either immediately before transplanting or, probably better, about one month after transplanting when the plants are well established and, until the plants have taken up the added nitrogen, the soil should be permanently covered with water. The best subsequent water regime will depend on the type of soil.

TABLE 15

Bucket trial on nitrogen application under varying water regimes

Layout 6 replicate buckets per treatment, 3 plants per bucket.
Treatments 1·5 grams sulphate of ammonia added to each bucket.

A—at planting
B—one month after planting
C—two months after planting
O—No nitrogen added.

Soils flooded to a depth of one inch

1—once a week
2—twice a week
3—permanently

Yields in grams/bucket

Water / *Fertilizer*	*1*	*2*	*3*	*Mean*
	Standard error ± 2·12			*S.E.* ± 1·24
O	21·6	21·9	21·5	21·6
A	24·1	30·9	33·1	29·4
B	24·2	30·6	30·6	28·5
C	19·8	23·9	20·6	21·4
Mean	22·4	26·8	26·4	25·2
	Standard error ± 1·06			

Coefficient of Variation 14·5%

Availability of phosphorus in swamp soils

As in most Sierra Leone rice soils phosphorus is often a limiting factor for yield and striking responses to added phosphorus are shown, a method for determining the available phosphorus in such soils was needed. No existing methods are wholly satisfactory for this purpose. Laboratory work has therefore been carried out to determine a suitable method, bearing in mind the following points: (a) the low phosphorus content of the soils necessitates its measurement by the molybdenum blue method; (b) the importance of elimination of iron interference with this method,

as large amounts of extractable iron occur in these soils; and (c) the need to devise a simple method, involving no critical refinements, that would serve to indicate the phosphorus status of a soil sufficiently well for advisory purposes in development of swamps for rice cultivation.

Iron interference was readily eliminated by passing the soil extracts through a cation exchange column.

Initial experiments were carried out using the method of Bray and Kurtz as modified at the East African Agriculture and Forestry Research Organization, and the Peech modification of the Truog method. A detailed experiment was then done to test the effects of the ratio of soil to extractant, the pH of the extracting solution and the time of extraction. This was done on three different soils. The results showed it best to use 2 grams of soil and 100 millilitres of extractant and to extract for 24 hours. They also showed that small variations in the final pH of the extracting solution alter the amount of phosphorus extracted. An extractant composed of 30 millilitres of 4 × Normal hydrochloric acid to 70 millilitres of water gave a final pH in the extracting solution of about 0·0 for all the soils examined and was the extractant adopted. There were no significant differences between the amounts of phosphorus extracted from a freshly obtained wet sample, a dried and stored sample, a very finely ground sample, and a sample dried and then submerged for periods up to 12 weeks. Thus, using extraction at pH 0·0, there is no need for elaborate precautions when collecting and preparing a soil sample; all that is needed is to dry it and grind it sufficiently finely to pass through a 2 millimetre mesh sieve.

The inorganic phosphorus fractions were determined by the Chang and Jackson method and the total organic phosphorus by the Walker and Adams method. These results are shown for soils tested, and compared with the figures obtained for available phosphorus by the present method, in Table 16.

TABLE 16

Determination of phosphorus in various soils

Figures in mg P/100g soil

Type of P	*Rokupr grass swamp*	*Mando grass swamp*	*Fresh mangrove swamp*	*Cultivated mangrove swamp*	*Kontobe grass swamp*
water soluble	0·2	0·2	0·2		
Al—P	trace	trace	0·6		
Fe—P	12·2	12·7	2·9		
Ca—P	2·0	2·8	2·5		
reducible Fe—P	0·0	0·0	0·0		
occluded Al—P	0·2	0·2	0·6		
total inorganic	14·6	15·9	6·8		
total organic (W & A)	27·7	39·3	48·5		
available at pH 0	7·4	17·0	9·0	13·5	about 4·0

From field experiments it has been found that Mando grass swamps and cultivated mangrove swamps show no significant response to phosphate application while responses are obtained on Rokupr grass swamps and Kontobe soils. The figures for available phosphorus obtained by the present method agree with these practical findings, and it is thus thought that the method will be of use in assessing phosphate requirements of newly developed swamps, in particular to determine which grass swamps will respond to phosphate and which will not.

Fertilizer Trials on Sierra Leone Soils

(a) *Inland flood plain soils at Kontobe*

Development for rice growing of the inland flood plain soils, or "bolis" as they are known in Sierra Leone, has been undertaken by the Sierra Leone Department of Agriculture for some years, but in general without great success. One of the main problems has been the low fertility of the soils and the consequent low yields of rice obtained. These flood plains occur as extensive alluvial deposits in valleys of the lateritic area in the north centre of the country. The soils have a depth of eighteen inches or more and a texture of silty clay loam to silty clay. In the rainy season they become heavily flooded but in the dry season dry out completely, the soil organic matter is then dehydrated and the soils become very light grey in colour. Natural vegetation is of short grasses. Kontobe is on such a low-fertility flood plain and the Department of Agriculture maintains a small experimental station there. Analytical results of the soils show that it is very low in nitrogen and available phosphorus and low in iron.

Early experiments by the Department of Agriculture indicated that there was a good response to phosphate application and also to lime. No response however could be obtained from nitrogen. Experiments on these soils have been carried out from Rokupr in the past three years and results to date have been briefly mentioned in the last two Annual Reports. These have confirmed that phosphate and lime in combination have given the greatest response. A further experiment was carried out this year using higher applications. Details are in Appendix C. Experiments have also been done in the past, and a further one carried out this year, on the effects of interactions of added organic matter and iron-rich soil with lime and phosphate. Whereas in the past two years organic matter showed a response, this year only the lime and phosphate responses were significant. Table 17 is a compilation of the yield figures of first year effects of lime and phosphate.

TABLE 17

Summary of lime and phosphate effects on Kontobe soils

P_1 = superphosphate at 1 cwt./acre
L_2 = dolomitic limestone at 2 tons/acre, etc.

Yields in lb./acre

	P_0	P_1	P_2	P_3	P_5	P_6	P_9
L_0	300	430	530	600	640	620	440
L_2	510	560	660	840	1120	1120	
L_4	600	660	720	1010	1090	1080	900
L_8	480	570	690	810	950	940	700

Experiments have been carried out on the residual effects of lime and superphosphate and it has been found that, while there are only small residual effects from superphosphate in the second year, the residual effects of lime are great and for several years.

Further experiments were carried out this year on nitrogen application (using sulphate of ammonia) at high levels of phosphate and lime, and on methods of planting and of water control, but no significant differences in yield apart from those directly due to lime and phosphate were shown. An observation subtractive experiment did however give the first indications of a possible nitrogen and potash response on land which has been cropped with rice for five years.

It is now possible to make certain recommendations for this area. An initial application of 2 tons per acre of lime and $2\frac{1}{2}$ cwt. per acre of double superphosphate (approximately 48% P_2O_5) should be given, and in following years $\frac{1}{2}$ to 1 cwt. per acre of double superphosphate. Further experimental work on application of nitrogen fertilizers other than sulphate of ammonia at different stages of growth should be undertaken. It will possibly be found necessary to give small applications of urea and potash annually. Further liming should not be needed for at least five years. The use of single superphosphate and sulphate of ammonia should probably be avoided on these low-iron soils.

(b) *Riverain grass-lands at Rokupr and Mando*

These are grouped together as experimental results have been very similar. At Rokupr, on the Great Scarcies river, these grass-lands occur in a narrow band between the uplands and the mangrove swamps, but on the Little Scarcies at Mando, where there are no mangrove swamps, they form wide areas adjacent to the river. They normally are dry for part of the dry season but are under varying wet conditions for the rest of the year. Fertilities are higher than the inland flood-plain soils, and the soils are high in iron.

Experiments on these soils have shown responses to phosphate, lime and organic matter, though no responses have been shown to added nitrogen fertilizers. Further experiments were carried out this year. At Mando, a residual experiment on the effect of lime which was significant in 1959 gave no significant results, largely due to flood damage. At Rokupr the residual effect of lime after three years is still significant. Results are in Appendix C.

(c) *Mangrove lands at Rokupr*

The soils were formerly under *Rhizophora racemosa* mangrove and have grown rice for a great number of years. They are flooded by tide-water from the river and remain permanently moist. Fertility is high and responses to fertilizers have not been found in the past. Experiments with lime, superphosphate and nitrogen were again tried this year without significant increases in yield. Increased yields have however been obtained from addition of organic matter. A further experiment this year using sulphate of ammonia carefully applied beneath the surface did however show some significant responses. This would seem to indicate that increased yields can be obtained from mangrove soils with nitrogen fertilization but that time and method of application must be carefully studied. This is in accord with recent work in the Far East. Results from experiments which showed significance are given in Appendix C.

Bucket experiments

Preliminary trials in buckets have given very good results, and it is considered that such trials should be carried out on soils of all areas being developed for rice cultivation. In particular they show up soils with severe phosphorus deficiencies, necessitating high initial phosphate applications. The method used is briefly as follows:

(a) Soil from the site under examination is crushed and thoroughly mixed, and then placed in thirty-two $2\frac{1}{2}$-gallon polythene buckets without drainage holes.

(b) The buckets are labelled as a 2^5 factorial experiment, without replication, for nitrogen, phosphorus, potash, lime and organic matter, and the appropriate standard fertilizers stirred in.

(c) Twelve seeds are sown in each bucket and the soil maintained just

waterlogged. After 14 days these are thinned out to three plants and from then on standing water up to $2\frac{1}{2}$ centimetres in depth is kept on the soil.

(d) Plants may be left until harvest but, if healthy growth takes place and there are no signs of over-fertility, it is not necessary to do this. In this case, after about 80 days growth, the plants are cut off at the soil surface, dried overnight in an oven at 110° Centigrade and weighed.

(e) The effects of the various treatments can then be calculated in the usual way, and the critical differences found by taking the least effective main treatment (usually potash) and one confounded interaction to form replicates.

APPENDIX A

METEOROLOGICAL RECORDS ROKUPR—1961

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Rainfall (25 year average)	0·00 (0·19)	0·00 (0·05)	0·27 (0·54)	1·67 (2·33)	4·03 (7·06)	10·40 (14·60)	22·78 (23·58)	32·43 (28·89)	25·74 (18·40)	12·54 (14·28)	9·34 (6·16)	0·00 (0·87)	119·10 (116·95)
Sunshine (20 year average)	234·2 (249·2)	234·4 (227·5)	255·8 (241·7)	231·4 (208·4)	215·0 (191·4)	157·9 (158·7)	90·1 (101·3)	77·9 (65·2)	145·2 (121·7)	245·2 (193·4)	238·2 (199·4)	255·9 (224·3)	2381·2 (2182·2)
Mean Maximum Temperature (20 year average)	91·1 (90·9)	92·5 (92·8)	92·6 (93·0)	92·5 (92·7)	91·5 (90·8)	86·7 (87·7)	83·3 (83·8)	81·7 (81·9)	84·2 (85·4)	88·1 (88·0)	88·9 (88·7)	90·6 (89·1)	88·6 (88·6)
Absolute Maximum Temperature (20 year record)	98 (102)	98 (101)	98 (102)	96 (103)	98 (101)	92 (99)	88 (98)	86 (91)	88 (99)	91 (96)	91 (99)	92 (97)	98 (103)
Mean Minimum Temperature (20 year average)	64·8 (68·3)	67·4 (69·7)	69·0 (71·6)	72·5 (73·0)	74·6 (73·5)	72·2 (72·4)	71·9 (72·1)	72·1 (72·0)	71·9 (72·3)	70·9 (71·7)	72·2 (71·8)	68·2 (69·5)	70·6 (71·5)
Absolute Minimum Temperature (20 year record)	55 (50)	58 (60)	68 (62)	68 (65)	69 (69)	68 (63)	64 (60)	70 (67)	68 (68)	68 (68)	70 (63)	61 (53)	55 (50)
Mean Relative Humidity a.m. (10 year average)	83 (88)	87 (87)	86 (84)	82 (82)	84 (84)	86 (89)	93 (92)	92 (93)	91 (92)	88 (89)	87 (89)	84 (88)	87 (88)
Maximum Relative Humidity a.m. (13 year record)	97 (100)	95 (100)	95 (100)	95 (100)	95 (100)	97 (100)	97 (100)	97 (100)	97 (100)	95 (100)	96 (100)	100 (100)	100 (100)
Mean Relative Humidity p.m. (10 year average)	45 (53)	56 (48)	48 (52)	55 (54)	63 (65)	72 (73)	84 (81)	87 (83)	80 (80)	67 (71)	65 (68)	51 (57)	64 (65)
Minimum Relative Humidity p.m. (13 year record)	15 (15)	18 (14)	28 (23)	28 (28)	36 (31)	56 (54)	67 (59)	70 (53)	68 (51)	51 (41)	55 (37)	31 (10)	15 (10)

Rainfall in inches. Sunshine in hours. Temperature in degrees Fahrenheit. Relative Humidity as percentages. Morning readings taken at 09.00 hours. Afternoon readings taken at 15.00 hours. Bracketed figures are averages and records.

APPENDIX B

RICES INTRODUCED – 1961

From Hong Kong

Pak Huk Chai Mei
Sam Sin Kuk
Kuk Tsai

From Korea

Paltal
Nongkwang

From Taiwan (Formosa)

Bir-Me-Fen
Chian-Nan
Hsinchu 56
Kaohsiung 68
Taichung (Native) 1
Taichung No. 1
Taichung 176
Taichung 179

via Nigeria

Taichu 65

From Philippines

Bengawan
Dinalaga

From Thailand

Leb Mue Nahng 111

From Pakistan

Panbira

From India

via Malaya

Tai Chu 65 × Siam 29 51/1/2
Tai Chu 65 × Siam 29 56/1
Tai Chu 65 × Siam 29 57/1
Tai Chu 65 × Siam 29 57/2
Tai Chu 65 × Mayang Ebos 80 30/1
Tai Chu 65 × Mayang Ebos 80 36/1
Tai Chu 65 × Mayang Ebos 80 42/1
Tai Chu 65 × Mayang Ebos 80 53/1
Tai Chu 65 × Mayang Ebos 80 75/1
Tai Chu 65 × Nachin 57 3/1/1
Tai Chu 65 × Nachin 57 11/1
Tai Chu 65 × Nachin 57 27/1
Tai Chu 65 × Nachin 57 36/1/2
Tai Chu 65 × Nachin 57 66/1
Tai Chu 65 × Serendah Kuning 8/1/2

From Surinam

S. M. L. 2. 42
Dimm
Skrivimankoti

From Senegal

Dissi Hatif (D.H.2)

From Nigeria

B.G.79 strain

APPENDIX C

RESULTS OF FERTILIZER TRIALS

(a) *Fertilizer trial with phosphate and lime at Kontobe*

Layout Randomized Block 6 replications.

Treatments Superphosphate (P) at 0, 3, 6 and 9 cwt./acre, Lime (L) at 0, 4 and 8 tons/acre.

Variety Parn A–191.

Plots 12 × 12 feet.

Area of plot harvested ·00185 acre (9 × 9 feet).

Yields in lb./acre

Lime \ *Phosphate*	P_0	P_3	P_6	P_9	*Mean*
	Critical Difference (5%) = 372				*C.D.* (5%) = 185
L_0	493	639	538	431	528
L_4	431	835	1036	823	786
L_8	493	823	952	711	749
Mean	472	766	842	655	684
	Critical Difference (5%) = 215				
Coefficient of Variation = 27·0					

(b) *Second year residual fertilizer trial on Rokupr grass swamp*

Layout Randomized Block 6 replications.

Treatments Superphosphate (P) at 0, 1, 2, and 3 cwt./acre, Lime (L) at 0, 2, and 4 tons/acre, applied in 1959.

Variety Toma 112.

Plots 12 × 12 feet.

Area of plot harvested ·00185 acre (9 × 9 feet).

Yields in lb./acre

Lime \ *Phosphate*	P_0	P_1	P_2	P_3	*Mean*
	Standard error ± 88				*S.E.* ± 44
L_0	1108	1155	1068	1399	1188
L_2	1054	1363	1332	1392	1292
L_4	1390	1485	1420	1496	1455
Mean	1184	1335	1273	1429	1305
	Standard error ± 51				
Coefficient of Variation = 16·5%					

(c) *Fertilizer trial on Rokupr cultivated mangrove swamp*

Layout 2^4 factorial with highest order interaction confounded. 6 replications.

Treatments Superphosphate (P) at 0 and 6 cwts./acre, Lime (L) at 0 and 4 tons/acre, Iron-rich soil (Fe) at 0 and 4 tons/acre, Organic matter (Om) (brushings) at 0 and 2 tons/acre.

Variety Lead.

Plots 12 × 12 feet.

Area of plot harvested ·00185 acre (9 × 9 feet).

Yields in lb./acre

	Fe_0	Fe_4	L_0	L_4	P_0	P_6	*Mean*
			Standard error ± 77				*S.E.* ± 54
Om_0	2063	2179	2281	1961	1997	2245	2121
Om_2	2305	2321	2413	2213	2187	2439	2313
Mean	2184	2250	2347	2087	2092	2342	2217
			Standard error ± 54				

Coefficient of Variation = 12%

(d) *Fertilizer trial with nitrogen and lime on Rokupr cultivated mangrove swamp*

Layout Randomized Block 6 replications.

Treatments Basal dressing of 3 cwts./acre superphosphate added throughout, Sulphate of ammonia (N) at 0, 1, $2\frac{1}{2}$ and 4 cwts./acre, Lime (L) at 0, 2 and 4 tons/acre.

Variety Lead.

Plots 12 × 12 feet.

Area of plot harvested ·00185 acre (9 × 9 feet).

Yields in lb./acre

Nitrogen / *Lime*	N_0	N_1	$N_{2\frac{1}{2}}$	N_4	*Mean*
		Standard error ± 112			*S.E.* ± 56
L_0	1525	1618	1678	1948	1701
L_2	1516	1569	1589	1682	1597
L_4	1531	1512	1812	1628	1629
Mean	1524	1566	1693	1753	1617
		Standard error ± 65			

Coefficient of Variation = 17%

CONVERSION FACTORS

To convert	*into*	*multiply by*
inches	millimetres	25·4
feet	metres	·305
acres	hectares	·405
lb/acre	kilo./hectare	1·121
cwt./acre	kilo./hectare	125·54
tons/acre	kilo./hectare	2511

TEMPERATURE CONVERSIONS

°*F*	°*C*	°*F*	°*C*
50	10·0	78	25·5
52	11·1	80	26·6
54	12·2	82	27·7
56	13·3	84	28·8
58	14·4	86	30·0
60	15·5	88	31·1
62	16·6	90	32·2
64	17·7	92	33·3
66	18·8	94	34·4
68	20·0	96	35·5
70	21·1	98	36·6
72	22·2	100	37·7
74	23·3	102	38·8
76	24·4	104	40·0